AN EVALUATION OF THE SUITABILITY OF ERTS DATA FOR THE PURPOSES OF PETROLEUM EXPLORATION

Dr. R. J. Collins, F. P. McCown, L. P. Stonis and
Gerald Petzel
Eason Oil Company
5225 North Shartel
Oklahoma City, Oklahoma 73118

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16. Abstract

During the past 6 months the continuing analysis phase of the experiment is well underway and results to date are encouraging. ERTS imagery seems to be good to excellent for reconnaissance level investigations of large sedimentary basins such as the Anadarko Basin. Many lithologic boundaries, and geomorphic features (such as stream patterns), and linear features inferred to be indicative of geologic structure are visible in the imagery. ERTS imagery in conjunction with high altitude photography seems to be useful as a tool for intermediate level geologic exploration. Several types of crudely circular anomalous features, such as geomorphic/structural anomalies, hazy areas and tonal anomalies, are identifiable in the imagery. There seems to be a strong correlation between the geomorphic/structural and hazy anomalies and known structurally controlled oil and gas fields.

The features recognizable on ERTS imagery and their ease of recognition vary from area to area even in imagery acquired at the same time under essentially uniform atmospheric conditions. Repeated coverage is exceedingly valuable in geologic applications. One time complete coverage even for the various seasons does not reveal all the features that ERTS can reveal.

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PREFACE

The objective of this experiment is to assess the value of ERTS-1 imagery for the purpose of petroleum exploration in large intercratonic sedimentary basins. Our data analysis plan has been approved and the continuing analysis phase of the experiment is well under way.

This report describes our activities during the past 6 months which have included interpretation of fall acquired imagery, preliminary interpretation of spring acquired imagery, preliminary analysis of the fall interpretations and correlation of these interpretations with existing literature, and initial work on various types of enhancement techniques.

Preliminary conclusions drawn from the interpretation and analysis thus far include the following:

- ERTS imagery seems to be good to excellent for reconnaissance level investigations of large sedimentary basins such as the Anadarko Basin. Many lithologic boundaries, and geomorphic features (such as stream patterns), and linear features inferred to be indicative of geologic structure are visible in the imagery. (Though many lithologic boundaries can be recognized in the ERTS imagery, it is not possible to identify rock types from the imagery except in a very few instances.)

- Results to date are encouraging for the use of ERTS imagery in conjunction with high altitude photography as a tool for intermediate level geologic exploration, i.e. investigation of features known to

be of exploration interest. Several types of crudely circular anomalous features, such as geomorphic/structural anomalies, hazy areas and tonal anomalies, are identifiable in the imagery. There seems to be a strong correlation between the geomorphic/structural and hazy anomalies and known structurally controlled oil and gas fields.

- ERTS imagery because of its poor resolution and other factors will probably be of limited use for detailed exploration such as choosing drilling sites except perhaps in some exceptional instances such as locations where fault related fracture porosity is important in controlling hydrocarbon accumulation.

Other conclusions of more limited scope that have grown out of our experience to date include the following:

- The features recognizable on ERTS imagery and their ease for recognition vary from area to area even in imagery acquired at the same time under essentially uniform atmospheric conditions. In the Anadarko Basin this is probably the result of encountering progressively dryer climates and overall higher elevations as one proceeds westward.

- Repeated coverage is exceedingly valuable in geologic applications. One time complete coverage even for each season does not show all the features that ERTS can reveal. Subtle changes in moisture content, atmospheric transparency, vegetation vigor or growth stage, etc., all enhance or supress different features to varying degrees.

- Interpretation on 1:1,000,000 scale transparencies and compilation on 1:250,000 scale mosaics is the most effective way we have found to interpret the imagery.

Our only recommendation at this point is that some more accurate method be devised for relating the center point coordinates and latitude-longitude tick marks on bulk images to actual coordinates.

INTRODUCTION

This is a Type II Progress Report on the Eason Oil Company ERTS experiment (#173, PR043) entitled "An Evaluation of the Suitability of ERTS Data for the Purpose of Petroleum Exploration". The report covers the period December 1972 through May 1973, and includes a review of Type I Progress Reports for periods December 72/January 73, and February/March 73, as well as a discussion of progress made during April/May 73.

To date we have received ERTS imagery that provides complete one-time coverage of the entire area and multiple coverage of much of the area. Data received are shown in the Appendix. We have received no precision processed data.

During this reporting period we have completed our first look analysis, and have received approval of our data analysis plan. We have begun the continuing analysis phase of the experiment and have completed preliminary detailed interpretation of all of the fall acquired imagery received and much of the spring imagery. We are now in the process of compiling, reviewing, and revising these interpretations.

We have prepared working and reference mosaics of most of the test area using (a) band 6, 1:1,000,000 paper prints, (b) color composite paper prints and (c) 1:250,000 paper prints of band 5. Because we are striving for tonal uniformity we have not completed the mosaics and are awaiting arrival of usable 70 mm negatives and color composites of frames 1130-16404, - 16410, and 16413.

Computer processing is underway. Manipulations that seem particularly promising at present are density stretching (gray scale expansions), edge enhancement using both directional derivatives and Laplacian transforms, and perhaps some classification schemes. Other forms of enhancement are also underway with the most promise being shown at present by optical color combining techniques using an I^2S Mini Addative Color Viewer. A preliminary conclusion from this work is that two-band combinations may be better than three-band combinations for particular purposes.

II. DISCUSSION OF RESULTS TO DATE

We had originally anticipated completing the experiment by this time. However, data has arrived somewhat more slowly than anticipated and the imagery contains much more information than we had originally anticipated, which necessitates more time for interpretation and analysis. Our revised estimate of completion is mid-September 1973.

A. Interpretation Methods

For our purposes the most efficient method of interpretation is to interpret 1:1,000,000 scale black and white and color transparencies on a light table using the unaided eye and low power (3X and 10X) magnification. The results are marked on transparent overlays. The data from the various frame areas are compiled on 1:1,000,000 scale overlays of the entire area. These data are also compiled on overlays to the 1:250,000 scale reference mosaics of ERTS imagery of the area.

B. Problems Encountered

Preliminary detailed interpretation of individual frames is nearly complete and compilation is underway. Overall the results are quite

encouraging. However, several technical problems have come to light, all of which we are certain you are aware, and none of which is insurmountable.

- Latitude ticks are incorrectly located on bulk processed (system corrected) imagery. Moreover, the amount of error varies from frame to frame. This necessitates matching terrain features during compilation rather than simply compiling using the latitude-longitude tick marks.

- Latitude lines are located 3 to 7 km . south of true position in our area.

- The scale of the 9.5 x 9.5 inch positive transparencies is slightly larger than 1:1,000,000 based on comparison with standard U.S.G.S. 1:1,000,000 base maps.

- By comparison with 1:250,000 U.S.G.S. topo maps the center points for frames are as much as 3 km. off. The center points printed on pictures differ from center points listed in the catalogue by as much as 10'.

C. Types of Interpretations and Results

During the course of interpretation we have found that in order to minimize confusion it is best to use separate overlays for different types of interpretation, such as lithologic boundaries, sub-circular anomalous areas, and linears. The imagery has proven useful for interpreting some of the major lithologic boundaries present in the area. This is particularly ture for the contact of Quaternary alluvial and colluvial deposits with Tertiary and Paleozoic rock units. The ability to map even

areas of old terrace (Pleistocene) deposits on the imagery is quite amazing. Some upper Paleozoic units can be distinguished, but some of the boundaries we had expected to see are not distinguishable.

It is worth noting that various boundaries are more easily seen on one band than on another. In general, bands 4 and 5 are best for seeing the boundaries between Quaternary and older units, and bands 6 and 7 are best for differentiating Paleozoic units. We have also found that images acquired at different times (even during the same season) emphasize the various boundaries to different degrees. This last point is important, because it implies that multiple coverage is required in geologic mapping of the central U.S. in order to derive maximum benefit from ERTS imagery, and that one-time coverage for each season will not provide all of the derivable information. This is because there are year to year climatic variations, (monthly mean temperature and rainfall) that produce a different overall vegetation response in addition to the short term weather changes that alter ground moisture, atmospheric transparency, creek runoff, etc. (which have produced the changes seen in the imagery seen to date), in semi-arid areas such as the Anadarko Basin. Each variation of wet season and monthly mean temperature will produce unique vegetation responses that enhance or supress recognition of various geologic features. These observations are particularly true for distinguishing lithologic boundaries, but also apply to detecting linears and anomalous tonal, geomorphic, and structural features.

The ERTS imagery received to date is excellent for detecting natural linear features in the landscape, which are interpreted to represent fractures. Because of their large number, we have found it convenient to interpret linears on separate overlays from other features. There are several sets of linears

present in the images. These linears are manifested as subtle dark or light lines across cultivated areas, straight abrupt tonal contrasts, alignments of straight stream segments, straight stream courses, and apparent offsets of lithologic contacts. We are skeptical about any north or east trending linears on the assumption that these are related to section line roads. Several of the linears detected coincide with known and mapped surface faults. Some linears parallel, but don't quite coincide with mapped subsurface features. Some long linears, extending as much as 60 to 100 km., are not mapped as faults or joints on published 1:250,000 and 1:500,000 scale geologic maps. These may be image artifacts of some type, but field work demonstrates, at least in the areas checked, that these features represent creeks controlled by closely spaced joints, whose trend is extended by the optical integration of many small straight features as a consequence of the relatively poor resolution and large area covered of the ERTS imagery. There are many more linear features, which we interpret as fractures (either faults or joints), visible in the ERTS imagery than are present on any geological maps of the area we have seen. The high altitude aerial photography (3 flight lines) provided by NASA, where present, corrobrates and extends the ERTS interpretation and provides a wealth of detailed information that assists in understanding the ERTS response to the terrain.

There are surprisingly few linears parallel to the Wichita-Amarillo Mountain front. We had expected this to be a dominant linear or fracture trend. It is possible that the lighting conditions produced by having the sun's azimuth essentially parallel to these trends tends to reduce their visibility. In contrast to the surprising paucity of mountain fromt or basin edge linears we have noted several long NE and NNE trending linears that do not appear on any of the published maps we have reviewed.

The imagery contains numerous crudely circular to irregularly shaped anomalous areas. These anomalies fall into three basic categories: geomorphic features assumed to be related to geologic structure, hazy or seemingly blurred areas, and tonal anomalies. Upon close examination many of the geomorphic anomalies are seen to be marked by annular and other unusual stream patterns suggesting structural domes or anticlines, differential compaction features over older topographic highs, or collapse features caused by solution of Permian evaporite rocks. Others are seen to be formed by intersecting linears. Many of the domal and anticlinal features, as would be expected, corresponde to known structurally controlled oil and gas fields and other buried non-producing structural features.* In instances where similar features have been field checked (Johnson, in preparation) there is little or no surface structure detectable. It seems that these features are surface manifestations of buried structures.

Some of the crudely circular tonal anomalies appear to be spots of slightly blurred or hazy imagery. Preliminary analysis indicates a close correlation between these features and known oil or gas fields*. The question is, are these tonal anomalies a function of the presence of a hydrocarbon bearing feature, or do they reflect man s efforts to extract the hydrocarbon (i.e. roads, well sites, pipe lines, seismic shot holes, truck tracks, etc.)?

* Maps used for comparison include 1:250,000 Geologic Atlas of Texas, 1:400,000+ Oil and Gas field maps, 1:250,000 U.S.G.S. topographic quadrangles, 1:250,000 structural contour maps of the top of the Arbuckle Limestone and other larger scale maps of scattered areas.

Other subtle tonal anomalies observed in the imagery do not seem to correlate with any known soil or lithologic features, vegetation/crop patterns, topographic or structural features. These may represent subtle and perhaps transient variations in soil moisture content.

D. Other Uses

We have also noted that areas underlain by alluvial aquifers show up clearly as areas of light tone on band 4 and 7 imagery. In several instances striking contrasts in apparent vegetation vigor registered in the ERTS imagery clearly show the fracture control of water distribution in these aquifers.

III. NEW TECHNOLOGY

The techniques used so far in this experiment are standard image handling and photo interpretation techniques and methods of geologic analysis.

IV. PROGRAM FOR THE NEXT REPORTING INTERVAL

During the next reporting period we plan to complete interpretation of the spring acquired imagery and continue analysis of the interpreted imagery including comparison of features interpreted with published literature and maps, and with available geophysical data, comparing features seen in the ERTS imagery with existing high altitude photography, and checking selected features on the ground.

In addition to these major efforts we hope toÑ

.Complete compilation of 1:250,000 and 1:1,000,000 working and reference mosaics.

.Complete testing of optical and electronic enhancement techniques.

.Complete evaluation of computer enhancement techniques.

V. CONCLUSIONS

A preliminary criterion for evaluating any exploration tool, methodology, or technology is its ability to "recognize" or identify known features or areas of exploration interest. The ultimate criterion for testing an exploration technique or method is whether it can help locate features of interest that were previously unknown or unrecognized. We are in the process of testing ERTS imagery against the first criterion. The results are quite encouraging. Testing of the imagery against the second criterion must await surface and subsurface verification of features of interest and, in the instance of petroleum exploration, ultimately, successful drilling. Having said this, the conclusions presented below are preliminary and must be subjected to further analysis and testing.

- ERTS imagery seems to be good to excellent for reconnaissance level investigations of large sedimentary basins such as the Anadarko Basin. Many lithologic boundaries, and geomorphic features (such as stream patterns), and linear features inferred to be indicative of geologic structure are visible in the imagery. (Though many lithologic boundaries can be recognized in the ERTS imagery, it is not possible to identify rock types from the imagery except in a very few instances.)

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season does not show all the features that ERTS can reveal. Subtle changes in moisture content, atmospheric transparency, vegetation vigor or growth stage, etc., all enhance or supress different features to varying degrees.

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APPENDIX

DATA PRODUCTS RECEIVED

Frame I.D.	Center Point Lat.	Center Point Long.	9.5"×9.5" Print 4 5 6 7	9.5"×9.5" ⊕ Trans. 4 5 6 7	70 mm Neg. 4 5 6 7	70 mm Pos. 4 5 6 7	Color Print / Trans	Tape	Date Acquired	RBV	Comments
1004 - 16403	34° 49'	98° 16'	✓ ✓		✓	✓			27 Jul. 72	70mm print ⊖ 1,2,3	
1007 - 16572	35° 42'	102° 14'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓			30 July '72		
1077 - 16461	36° 03'	99° 13'	✓ ✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓ ✓			8 Oct '72		
1077 - 16463	34° 38'	99° 41'	✓ ✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1094 - 16404	35° 56'	97° 53'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			25 Oct 72		
1094 - 16411	34° 31'	98° 16'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1095 - 16460	37° 37'	98° 8C'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			26 Oct 72		
1097 - 16582	34° 28'	102° 42'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			28 Oct. 72		
1111 - 16351	35° 51'	96° 33'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			11 Nov. 72		
1111 - 16354	34° 25'	97° 00'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1114 - 16523	36° 00	100° 48'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			14 Nov 72		
1114 - 16525	34° 34'	101° 15'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1130 - 16404	37° 23'	97° 28'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		30 Nov 72		
1130 - 16410	35° 57'	97° 55'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1130 - 16413	34° 31'	98° 22'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓		"		
1131 - 16462	37° 24'	98° 54'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		1 Dec 72		
1131 - 16465	35° 58'	99° 22'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		"		
1131 - 16471	34° 33'	99° 49'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		"		
1132 - 16521	37° 22'	100° 21'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		2 Dec. 72		
1132 - 16523	35° 56'	100° 48'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓		"		
1132 - 16530	34° 30'	101° 15'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1220 - 16405	37° 2C'	97° 33'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			28 Feb '73		
1221 - 16473	34° 3C'	99° 55'	✓ ✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓			1 Mar 73		
1222 - 16531	34° 3C'	101° 20'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			2 Mar '73		
1223 - 16590	34° 37'	102° 4C'	✓ ✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓			3 Mar 73		
1237 - 16354	3C° 01'	96° 39'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			17 Mar 73		
1237 - 16360	34° 34'	97° 0C'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓			"		
1238 - 16410	37° 2C'	97° 37'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			18 Mar 73		
1238 - 16412	36° 00'	98° 04'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1238 - 16415	34° 35'	98° 31'	✓ ✓ ✓ ✓		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1241 - 16581	37° 30'	101° 54'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓					21 Mar 73		
1241 - 16584	36° 04'	102° 21'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓					"		
1241 - 16590	34° 39'	102° 48'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓					"		
1240 - 16523	37° 29'	100° 28'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			20 Mar '73		
1240 - 16525	36° 03'	100° 55'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1240 - 16532	34° 37'	101° 21'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		

Frame I. D.	Center Point Lat.	Center Point Long.	9.5×9.5" Print 4 5 6 7	9.5×9.5" ⊕ Trans. 4 5 6 7	70mm. Neg. 4 5 6 7	70mm. Pos. 4 5 6 7	Color Print. Trans.	Tape	Date acquired	RBV	Comments
1255-16354	N 36° 05'	W 96° 47'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			4 Apr. '73		
1255-16361	N 34° 38'	W 97° 07'	✓ ✓ . ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1256-16410	37° 30'	97° 35'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			5 Apr. '73		
1256-16412	N 36° 05'	W 98° 06'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1256-16415	N 34° 39'	W 98° 33'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1257-16464	N 37° 32'	W 99° 05'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			6 Apr. '73		
1257-16471	N 36° 07'	W 99° 32'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1257-16473	N 34° 41'	W 99° 59'		✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1273-16354	36° 10'	96° 39'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			22 Apr. '73		
1273-16380	34° 44'	97° 07'	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			"		
1275-16473	34° 43'	100° 00	✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓			24 Apr. '73		
1275-											